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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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T_1, T_2 and T_3. Regression analyses revealed that there was no difference in speed across all RPE between the three trials, however, HR was seen to become progressively higher during T_2 and T_3 than during T_1 as speed and RPE decreased. HR reliability was significant ($p<.05$) during running but not significant ($p>.05$) during walking. It is concluded that prescription of exercise by RPE can produce safe, effective and reliable conditioning HR above 150 beats/min (80% HR max) and running speeds above 9 km/hr (5.6 mph). Use of RPE for exercise prescription below these levels can result in inaccurate and unreliable conditioning heart rates. This method of exercise prescription has limitations and could result in dangerously high HR if used in cardiac rehabilitation programs for patients in which strict adherence to target HR is essential.

SUBJECTIVE REGULATION OF EXERCISE INTENSITY

BY PERCEIVED EXERTION

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Running Head: Rated Perceived Exertion and Exercise Regulation

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Abstract

The primary purpose of this investigation was to determine if a safe and effective physical conditioning heart rate (HR) could be prescribed by perception of exertion. Ratings of perceived exertion (RPE) were requested from ten normal adult males during treadmill exercise trials at 4.7, 6.5, 9.7, 11.3, and 12.9 km/hr (T_1). Subjects were then requested to subjectively regulate their own treadmill speed during two separate trials (T_2 and T_3) at the RPE reported for each speed during T_1. Speed and HR at equivalent RPE were compared during T_1, T_2 and T_3. Regression analyses revealed that there was no difference in speed across all RPE between the three trials, however, HR was seen to become progressively higher during T_2 and T_3 than during T_1 as speed and RPE decreased. HR reliability was significant ($p < .05$) during running but not significant ($p > .05$) during walking. It is concluded that prescription of exercise by RPE can produce safe, effective and reliable conditioning HR above 150 beats/min (80% HR max) and running speeds above 9 km/hr (5.6 mph). Use of RPE for exercise prescription below these levels can result in inaccurate and unreliable conditioning heart rates. This method of exercise prescription has limitations and could result in dangerously high HR if used in cardiac rehabilitation programs for patients in which strict adherence to target HR is essential.

KEY WORDS: Exercise prescription; heart rate; perceived exertion; speed; subjective regulation.

The recent popularity of physical conditioning for preventative as well as rehabilitative purposes necessitates an increased awareness and concern for safe and effective exercise prescription. The prescription of conditioning programs for individuals unaccustomed to regular physical exercise involves consideration of the type of physical activity along with the duration, frequency and intensity of that activity. Exercise intensity is often prescribed at approximately 70% of an individual's maximum functional aerobic capacity (maximum oxygen uptake). There is a linear relationship, except when approaching maximum, between oxygen uptake and heart rate during dynamic exercise involving large muscle groups.[1,2] Consequently, the intensity is often prescribed as a percent of maximum heart rate[3,4] or as a percent of maximum heart rate minus resting heart rate in the form of a target heart rate.[5] These methods are widely used today and necessitate the monitoring of heart rate either by some mechanized device (ECG or pulse counter) or by the exerciser counting his own pulse. Although this last method is popular and has proven satisfactory, errors in determining heart rate have been shown to occur due to pulse counting errors,[6] effects of palpation site[7] and also from the time delay encountered during post exercise pulse location.[8,9]

It has been suggested by Borg that some people have difficulty counting heart rate.[10] On the other hand, if no trouble is encountered they tend to become "pulse counters". Thus they focus too much attention on this activity becoming mentally preoccupied with it. Borg's psychophysical scale for ratings of perceived exertion (RPE) has been shown to have a high correlation with heart rate.[10,11,12]

The Borg psychophysical scale has been used almost exclusively to elicit a perceptual response to an exercise stimulus. Little work has been done using the

1

perceived exertion scale to set and adjust exercise intensity. If subjects are able to set and regulate their exercise intensity by perceptual feelings it may be possible to supplement the exercise prescription with subjective estimates of exertion. Once a subject's perceptual response to a particular standardized exercise (i.e. walking and running) is known it may be feasible to prescribe the intensity by perceptual feelings alone, under the same standard conditions. The primary purpose of this study was to investigate the difference in exercise intensity (speed of walking and running and heart rate) at the same RPE during standardized exercise of predetermined speed and exercise in which speed was subjectively regulated.

Methods

SUBJECTS AND DESIGN

Ten healthy male volunteers were selected as experimental subjects. These subjects had an average age (mean $\pm$ SD) of 25.5 ± 2.7 years (range 20 to 29); height, 175.6 ± 7.7 cm; weight, 76.4 ± 9.5 kg; maximal oxygen uptake, 55.4 ± 8.0 ml/kg·min; maximal heart rate, 189 ± 9.1 beats/min; and maximal rated perceived exertion, 19.5 ± 0.5. There were no cardiovascular, respiratory, orthopedic or metabolic conditions contraindicating exercise in any of the subjects. No one was currently under the care of a physician nor was anyone taking prescribed medications. All subjects were totally informed as to the plan and risk in the experiment and signed an informed consent form. Maximal oxygen uptake ($\dot{V}O_2$ max) was measured for each subject using a modified version of the treadmill test described by Taylor et al.[13]

Pre-recorded instructions for the Borg Scale of rated perceived exertion were played while the subject read a written copy. The scale for eliciting RPE is a bipolar scale with numbers from 6 to 20 (see Figure 1). Every odd number has an attached verbal expression ranging from "very, very light" at 7 to "very, very hard" at 19.

2

INSERT FIGURE 1 ABOUT HERE

Exercise trials (T_1) at 4.7, 6.5, 9.7, 11.3, and 12.9 km/hr (3, 4, 6, 7, and 8 mph) on a level treadmill were administered in order to measure heart rate, oxygen uptake, minute ventilation, and RPE at each speed. Subjects were exercised at each speed, presented in progressive order, for a five minute period. Heart rate, oxygen uptake and rated perceived exertion were measured during the last minute of exercise. An appropriate rest period, determined by the recovery heart rate, followed each trial. If the heart rate during the previous trial did not exceed 110 beats/min the heart rate was allowed to recover to resting before the next trial was started. When the heart rate exceeded 110 beats/min during the previous trial the heart rate was allowed to recover to 100 beats/min before the start of the next trial.

Exercise trials were then administered at several subjective intensities (T_2). The subjective intensities were the same RPE values the subject reported during the trials of T_1. These RPE values were presented in random order. The subjects first listened to pre-recorded instruction explaining the adjustment of treadmill speed according to perceived exertion. They then began walking at 3.5 km/hr (2.2 mph) on the level treadmill and were allowed to adjust their own speed, having access to the treadmill controls; the speed indicator dial was blinded from view. Four minutes were allowed for adjustment at the assigned RPE value. Warnings were given at 2, 3, and 3.5 minutes during the trial so that final adjustments could be made. At the end of the fourth minute the controls were removed from the subject's reach. Measurement of speed, heart rate and oxygen uptake were taken a minimum of one minute following the last speed

3

adjustment (or between the fifth and sixth minute of each trial). Rest periods as outlined in the previous section followed each trial.

Exercise trials (T_3) were administered at the same subjective intensities as T_2 for determining reproducibility. The RPE values were the same; however, the order in which they were presented was randomized once again. All other procedures were identical to those of T_2. The time period between trials (T_1, T_2 or T_3) ranged from a minimum of 3 days to a maximum of 7 days.

PROCEDURE

Oxygen uptake (STPD) during each trial of T_1, T_2, and T_3 were calculated using the same formulas presented by Consolazio et al.[14] Expired air was collected in a 150 liter meteorological balloon. Oxygen and carbon dioxide concentrations were determined with a Beckman E-2 oxygen analyzer and an LB-2 carbon dioxide analyzer, respectively. Expired volume was measured by drawing the air into a Tissot chain compensated spirometer. Heart rate was determined from a modified V_5 lead (i.e. negative on mid-sternum, positive on V_5, and ground on right chest) using a Hewlett Packard 1500B electrocardiograph. Overall ratings of perceived exertion were requested by the standardized statement, "rate your exertion".

STATISTICAL TREATMENT

Analysis of variance with repeated measures was used to test for differences in speed, heart rate and oxygen uptake of each mean RPE during T_1, T_2 and T_3. Pearson product-moment correlation coefficients and regression equations were computed between RPE and speed, heart rate, minute ventilation and oxygen uptake for T_1, T_2 and T_3. Reliability coefficients between T_2 and T_3

for each variable at corresponding RPE were computed using the Pearson product-moment correlation formula. Mean percent error in heart rate between T_1 and the average of T_2 and T_3 at each RPE was calculated. Mean percent error in heart rate between T_1 and the average of T_2 and T_3 across all RPE was calculated for each individual subject.

Results

The descriptive data presented in the methods indicate the group to be young adults of average height and weight while maximum $\dot{V}O_2$ suggests the group is of above average fitness level. The mean RPE reported at maximum confirms an appropriate rating response at maximum exercise levels.

Table 1 illustrates the means of RPE reported at each predetermined speed trial during T_1. The individual RPE for each subject ranged from 7 at the slowest speed to 18 at the fastest. The RPE values suggest the subjects were able to rate their perceptions of exertion appropriately during low and high intensity exercise. Mean RPE can be seen to increase as speed increased. A walking speed increment of approximately 1.7 km/hr (1 mph) elicited an RPE increment of about 2 rating units. Increments in running speed on the order of 1.7 km/hr (1 mph) resulted in increases in RPE of approximately 1 rating unit. All subjects were able to complete 5 minutes of exercise at each of the speeds with the exception of the 12.9 km/hr (8.0 mph) trial. Three of the subjects were stopped during this trial because their exertion rating reached the predetermined end point of greater than 18.

Each subject walked at 4.7 and 6.5 km/hr (3 and 4 mph) and ran at 9.7, 11.3, and 12.9 km/hr (6, 7 and 8 mph) during T_1. Subjects chose the same mode of exercise (walking or running) during T_2 and T_3 when regulating their own speed according to RPE reported for the 4.7, 9.7, 11.3 and 12.9 km/hr (3, 6, 7, and 8 mph) T_1 trials. In contrast, six subjects preferred to run during T_2 and T_3 at the RPE level they reported for the 6.5 km/hr (4 mph) T_1 trial. This represented a change in mode of exercise (from walking to running) for 60% of the subjects at mean RPE 10.3 between the standardized (T_1) and the subjectively regulated (T_2 and T_3) exercise trials.

INSERT TABLE 1 ABOUT HERE

Figure 2 graphically demonstrates the relationship of the regression lines comparing speed to RPE during T_1, T_2 and T_3. Correlation coefficents (r) of .83 and above in T_1, T_2 and T_3 demonstrate a significant positive relationship between RPE and speed in each trial. The slopes of individual regression equations are very near .80 in each trial; y-intercepts for each trial are close to each other. The individual linear regression lines relating speed to RPE in T_1, T_2 and T_3 can be seen to be nearly parallel and fall in close proximity to one another. The regression lines exhibit this very close relationship at all speeds and RPE.

6

Figure 3 displays the relationship of the regression lines relating HR to RPE during T_1, T_2, and T_3. Correlation coefficients of .85 and above in T_1, T_2 and T_3 indicate a strong positive relationship between HR and RPE during each trial. During the two subjectively regulated trials (T_2 and T_3) the slopes (.093 and .088) and y-intercepts (-1.96 and -1.39) of the regression equations did not differ appreciably. The similarity of the regression lines for the T_2 and T_3 trials is evident at all RPE and HR. The slope of the individual regression equation for T_1 is not as steep as the slopes for T_2 and T_3. The y-intercept of T_1 is higher than those for T_2 and T_3. The individual regression line relating HR to RPE in T_1 diverges from the regression lines in T_2 and T_3 as HR and RPE decline. The standard (T_1) and subjectively regulated trials (T_2 and T_3) manifest similarities only near maximum HR (> 180 beats/min). A progressive difference in HR at the same RPE occurs between standard and subjectively regulated exercise as HR declines from maximum.

Table 2 lists the Pearson product-moment correlation coefficients (r) between RPE and speed, HR, $\dot{V}_E$, and $\dot{V}O_2$ during T_1, T_2 and T_3. The r values range from .81 to .90 and all are significant at the .05 level. Each variable

7

demonstrates a strong positive relationship to RPE during standard as well as subjectively regulated exercise.

Test - retest reliability coefficients for speed, HR and $\dot{V}O_2$ between T_2 and T_3 are listed in Table 3. Reliability of the subjective regulation of speed was significant above RPE 10. At RPE below 10, HR and $\dot{V}O_2$ reliability was not significant at the .05 level. At lower RPE (< 10), HR and oxygen uptakes at the same RPE are not reliable even though speed is reliably regulated.

INSERT TABLE 2 ABOUT HERE

INSERT TABLE 3 ABOUT HERE

Table 4 presents the percent difference in HR between standardized (T_1) and the mean of the subjectively regulated trials (T_2 and T_3) at the same RPE level, $\dfrac{\overline{HR}_{T_{2,3}} - HR_{T_1}}{HR_{T_1}}$, for each individual at each RPE. Mean values for accuracy at each mean RPE reveal 22.3 and 34.7% differences in HR occurring at RPE of 7.9 and 10.3, respectively. HR differences were below 5.5% for RPE above 12. A general trend of improved accuracy with increasing RPE can be seen. Mean percent differences in HR between T_1 and the mean of T_2 and T_3 for each individual across all RPE ranged from 41% for the least accurate

8

subject (# 6) to 1.2% for the most accurate (# 7). A wide range of intra-individual HR differences across all RPE can be seen. Interindividual HR differences ranged from 100 to 3% for the RPE with the greatest mean difference (10.3) and from 7 to 0.3% for the RPE with the least mean differrence (14.6). Above RPE 7.9 interindividual differences decrease as RPE ascends. There was also less variability between subjects as speed increased.

INSERT TABLE 4 ABOUT HERE

Discussion

COMPARISON OF SPEED AND HR REGRESSION DURING STANDARD AND SUBJECTIVELY REGULATED EXERCISE

This investigation has demonstrated that at equivalent RPE the subjectively regulated speed during treadmill exercise is the same as the predetermined treadmill speed of a standardized exercise test (Figure 2). On the other hand, when heart rates during standard exercise are compared to subjectively regulated exercise at the same RPE the differences become progressively larger as HR declines (Figure 3). The HR regression lines indicate that at the same RPE, heart rates were higher during subjectively regulated exercise than during the standard exercise test. The HR difference between standard and subjectively regulated exercise is accentuated at lower RPE, speeds and absolute HR levels.

The point at which the HR divergence between standard and subjectively regulated exercise becomes significant has been established statistically. Analysis of mean HR variance at each mean RPE illustrates significant ($p < .05$)

9

differences in HR occur between standard and subjectively regulated exercise below approximately 150 beats/min (80% HR max) or RPE 12. At RPE 12, Figure 3 displays the speed (at which HR become significantly different) to be approximately 9 km/hr (5.6 mph).

Although the regression lines for speed are nearly identical during standard and subjectively regulated exercise the HR regressions demonstrate significant divergence at speeds below 9 km/hr. The discrepency in HR in the fast walking speed range (6 to 8 km/hr or 4 to 5 mph) may be explained by the fact that during the standard exercise trial all subjects walked when presented with the 6.4 km/hr speed. During the subjective regulation trials six subjects adjusted their speed to running at the same RPE. Noble and associates have shown that at the same RPE, heart rate for running is greater than walking.[15] Åstrand and Rodahl report oxygen uptake to be higher for running than walking at all speeds below 8 km/hr.[16] Assuming linearity with oxygen consumption, HR will also be higher. Since 60% of the subjects in this study preferred to change their mode of exercise (from walking to running) between the standard and subjectively regulated trials, the mode change may be responsible for the higher HR seen in T_2 and T_3.

Discrepancies in HR at the slower walking speed range (5 to 6 km/hr or 3 to 4 mph) were also noted. The mean speed at the lowest RPE was 2.9 mph during T_1 and 3.3 mph during T_2 and T_3. The increment of .40 mph between the trials resulted in a significant increase in HR. LeBlanc has reported that in young military men a minimum increment of only .25 mph in walking speed is necessary to evoke a significant increase in HR.[17] The speed increment (demonstrated in the present investigation) of approximately twice the minimum requirement to elicit a significant HR increase is shown not to be perceptually different when using RPE to adjust speed.

Comparison of speed and HR regression during exercise intensities reported and regulated by perceived exertion suggests that this group of subjects relied on sensations of speed (arising from a combination of stride length and leg motion) to subjectively adjust intensity, expecially at low exercise intensities. Ekblom and Goldbarg first suggested the possible importance of feelings of strain in the working muscles as important cues in determining RPE.[18] They hypothesized that an individual will evaluate his perceived exertion during exercise on the basis of at least two factors: a local factor, i.e. the feeling of strain in the working muscles, and a central factor, i.e. perceived tachycardia or tachypnea. Others support the importance of this two factor theory in the regulation of effort sensations.[19] The present finding lends support to the involvement of local factors in rating perceived exertion and also in regulating exercise by perceived exertion.

RELATIONSHIP BETWEEN SPEED AND EXERCISE MODE DURING STANDARD AND SUBJECTIVELY REGULATED EXERCISE

Noble et al. have described a perceived exertion intersection point (PEIP) as the point at which walking and running are perceived to be the same.[15] This point is suggested to occur at approximately 6.9 km/hr (4.3 mph). In the present study the subjects were made to walk at 6.4 km/hr (4 mph) during the predetermined speed trial. The fact that 60% of the subjects changed mode when adjusting their own speed at this RPE lends support to a PEIP within the 4 mph range.

CORRELATIONS DURING STANDARD AND SUBJECTIVELY REGULATED EXERCISE

The correlation between RPE and HR (r = .87) during the standard treadmill exercise trial is in close agreement with previous investigators; r = .85, reported by Borg[11] and r = .87 reported by Edwards et al.[12] A correlation of .86 between RPE and $\dot{V}_E$ obtained in this study approximates the correlations of .90 obtained by Edwards et al.[12] The r value of .87 for RPE versus $\dot{V}O_2$ closely approaches values of r = .88 and r = .92.[12,20] During the subjectively regulated trials the coefficients of correlation between RPE and the above mentioned variables did not differ significantly from the coefficients during the standard exercise. These findings reflect a similar magnitude of relationship or strong association between variables when RPE is used to regulate exercise intensity.

RELIABILITY OF SUBJECTIVE EXERCISE REGULATION

Coefficients of reliability during the subjectively regulated exercise trials are significant for speed across all RPE studied. HR and $\dot{V}O_2$ are reliable at RPE of 10.3 and above in this group of subjects. Failure of HR to be reliable at speeds in the 5 km/hr or 3 mph (RPE 7.9) range may be due to a greater HR variability within subjects at this low exercise intensity. The previously mentioned study demonstrated that minimum change in walking speed (.25 mph) can significantly change HR.[17] This study has shown that a walking speed change (.40 mph) of nearly twice the minimum is not perceptually different when adjusting exercise intensity by RPE. A significant variability in HR during walking has been demonstrated even though speed adjustments were not significantly different. In essence, the lack of HR reliability during walking supports the finding of HR regression line divergence at low exercise intensities.

ACCURACY IN ATTAINMENT OF PRESCRIBED HR DURING SUBJECTIVE EXERCISE REGULATION

The standardized exercise test (T_1) of this experiment was designed in order to 'calibrate' each subject's perceptual response with his HR. The subjects then regulated their own exercise intensity $(T_2$ and $T_3)$ at each of the 'calibration points' (RPE). In effect, exercise was prescribed at each of the subjective RPE levels. The percent differences in HR, $\dfrac{\overline{HR}_{T_{2,3}} - HR_{T_1}}{HR_{T_1}}$, between the standard and subjectively regulated exercise trials was computed at each subject's RPE (Table 4). This percent difference is a measure of percent error in exercise HR that occurred when subjectively regulated exercise was compared to the standard exercise test of the same RPE.

An accurate determination of HR during exercise is necessary in conditioning programs that prescribe exercise intensity by HR. The post exercise 10 second pulse count has been shown to estimate exercise heart rate with a mean error of 2 to 5.7% in strenuous exercise (80-90% HR max).[8,9] During exercise intensities of 70% and 62% maximum HR, McArdle et al., report mean errors of 7.6 and 13.5%, respectively.[8] The present study demonstrates mean errors in exercise HR of 1.8 to 5.5% during running in the 78 to 92% maximum HR range (RPE 12.5 to 14.6) when subjects regulated intensity by perceived exertion alone. Mean errors of 22.3 and 34.7% were found during walking in the 49 to 73% HR max range (RPE 7.9 to 10.3). A comparison of the previously reported exercise HR errors estimated by pulse counting with the subjectively regulated HR errors computed in this study demonstrates no difference in accuracy during running at high (> 78% max) heart rates.

13

Table 4 also includes mean percent differences in HR across all RPE for each subject individually. The large range of intraindividual HR error across all RPE suggests that some individuals are far more accurate in subjectively regulating their exercise intensity by RPE. Although the intraindividual HR accuracy improves at higher speeds and heart rates, these individual differences must be taken into account if this method of prescription is to be used in instances where limits of prescribed target HR must be strictly enforced (i.e. cardiac rehabilitation programs).

CLINICAL CONSIDERATIONS

The subjective regulation of exercise intensity by perceived exertion investigated in this study shows potential for its use as a clinical method of exercise prescription in normals above intensities of 80% HR max, and 9 km/hr (5.6 mph). For individuals with restricted maximal heart rates (lower age adjusted max HR) this method may have limited value. A group of this nature would also include cardiac patients in whom accurate determinations of exercise HR may be a matter of life and death. Secondly, many patients, have relatively low symptom - limited maximal heart rates requiring their conditioning programs to consist of only low level walking. The subjective regulation of walking exercise in this investigation has been shown to be inaccurate when considering HR as the measure of exercise intensity.

14

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1. The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

2. Human subjects participated in these studies after giving their free and informed voluntary consent.

FIGURE LEGENDS

Fig. 1 - The Borg category rating scale for ratings of perceived exertion (RPE).

Fig. 2 - Linear regression lines comparing speed to rated perceived exertion during T_1, T_2 and T_3 (T_1 = standized exercise test; T_2 = subjectively regulated exercise test; and T_3 = retest of T_2).

Fig. 3 - Linear regression lines comparing heart rate to rated perceived exertion during T_1, T_2 and T_3. Abbreviations the same as previous figure.

Table 1: Mean RPE Reported during Predetermined Speed Trials (T_1).

Speed			RPE		
km/hr	mph		mean	$\pm$ SD	N
4.7	3		7.9	1.1	10
6.5	4		10.3	1.6	10
9.7	6		12.5	1.4	10
11.3	7		13.9	2.1	10
12.9	8		14.6	2.1	7

Table 2: Pearson Product - Moment Correlation Coefficients between RPE

and Speed, HR, $\dot{V}_E$, $\dot{V}O_2$.

	Speed	HR	$\dot{V}_E$	$\dot{V}O_2$
T_1	.83	.87	.86	.87
T_2	.85	.87	90	.81
T_3	.85	.85	.90	.82

p > .05 = non-significant (*)

21

Table 3: Test - Retest Reliability Coefficients

at Mean RPE between T_2 and T_3.

	RPE				
	7.9	10.3	12.5	13.9	14.6
Speed	.82	.94	.92	.74	.93
HR	.52*	.92	.91	.86	.91
$\dot{V}O_2$	.48*	.93	.92	.83	.94

$p > .05$ = non-significant(*)

Table 4: Individual Percent Differences in HR between

$$T_1 \text{ and the Mean of } T_2 \text{ and } T_3 \quad \frac{\overline{HR}_{T_{2,3}} - HR_{T_1}}{HR_{T_1}} \quad .$$

Negative Value indicates Lower HR in $T_{2,3}$ Compared to T_1 at the Same RPE.

S	RPE						
	7.9	10.3	12.5	13.9	14.6	MEAN	± SD
1	-3.5	-2.7	-18.7	-1.2	----	-6.5	8.2
2	16.5	41.4	1.8	-0-	2.3	12.4	17.5
3	13.6	59.3	4.2	4.1	----	20.3	26.4
4	12.7	22.3	8.7	-3.6	-4.3	7.2	11.3
5	25.5	27.1	5.4	3.6	----	15.4	12.6
6	71.6	99.6	28.5	12.0	-6.8	41.0	43.7
7	13.0	13.6	-6.1	-8.2	-6.4	1.2	11.1
8	38.1	37.6	-2.4	- .3	-1.9	14.2	21.6
9	17.0	26.4	14.7	8.2	.3	13.3	10.0
10	18.8	22.4	i8.6	6.5	4.4	14.4	8.1
MEAN	22.3	34.7	5.5	2.!	-1.8		
± SD	20.2	28.2	13.3	6.0	4.3		

6

7 Very, Very Light

8

9 Very Light

10

11 Fairly Light

12

13 Somewhat Hard

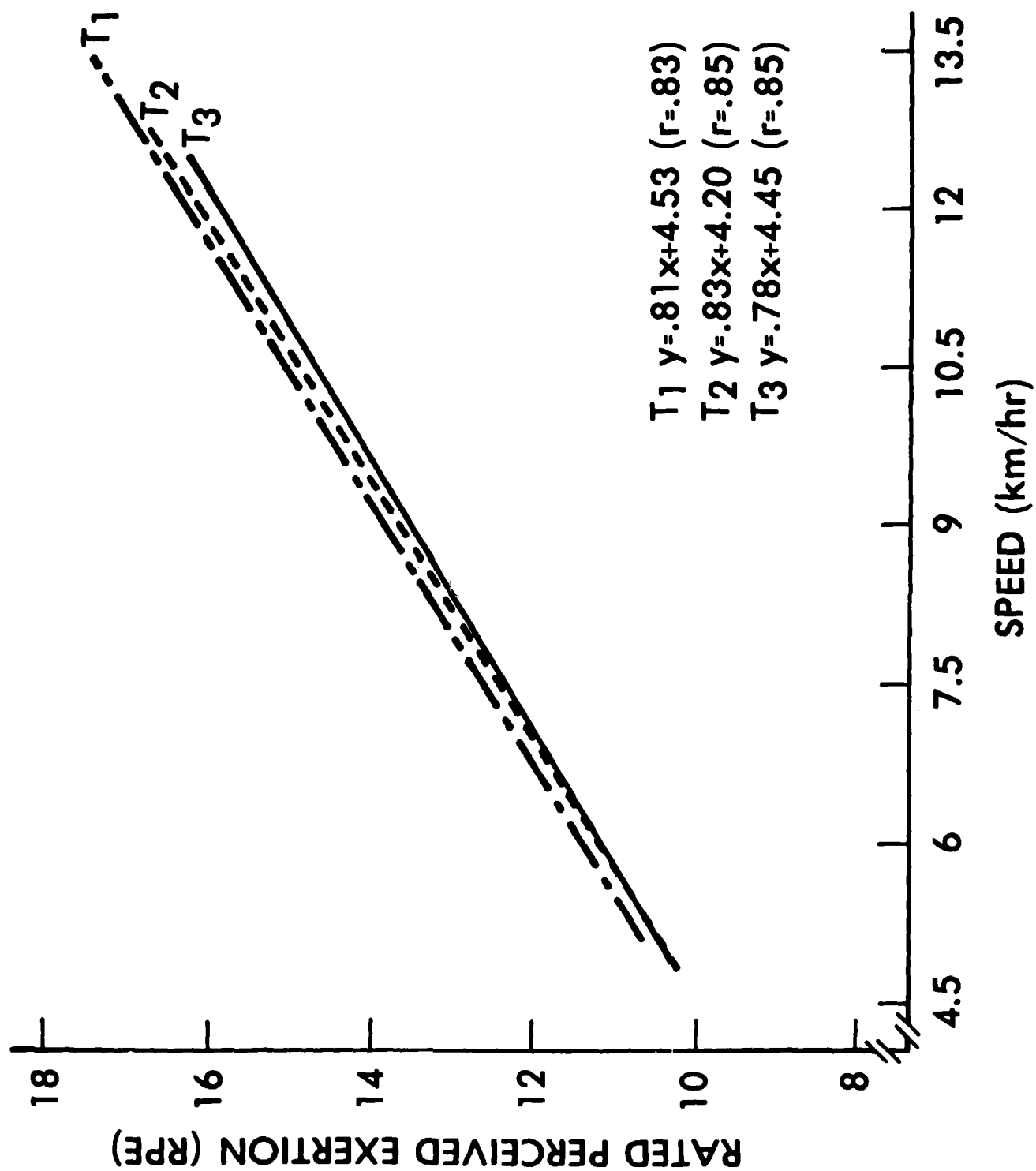14

15 Hard

16

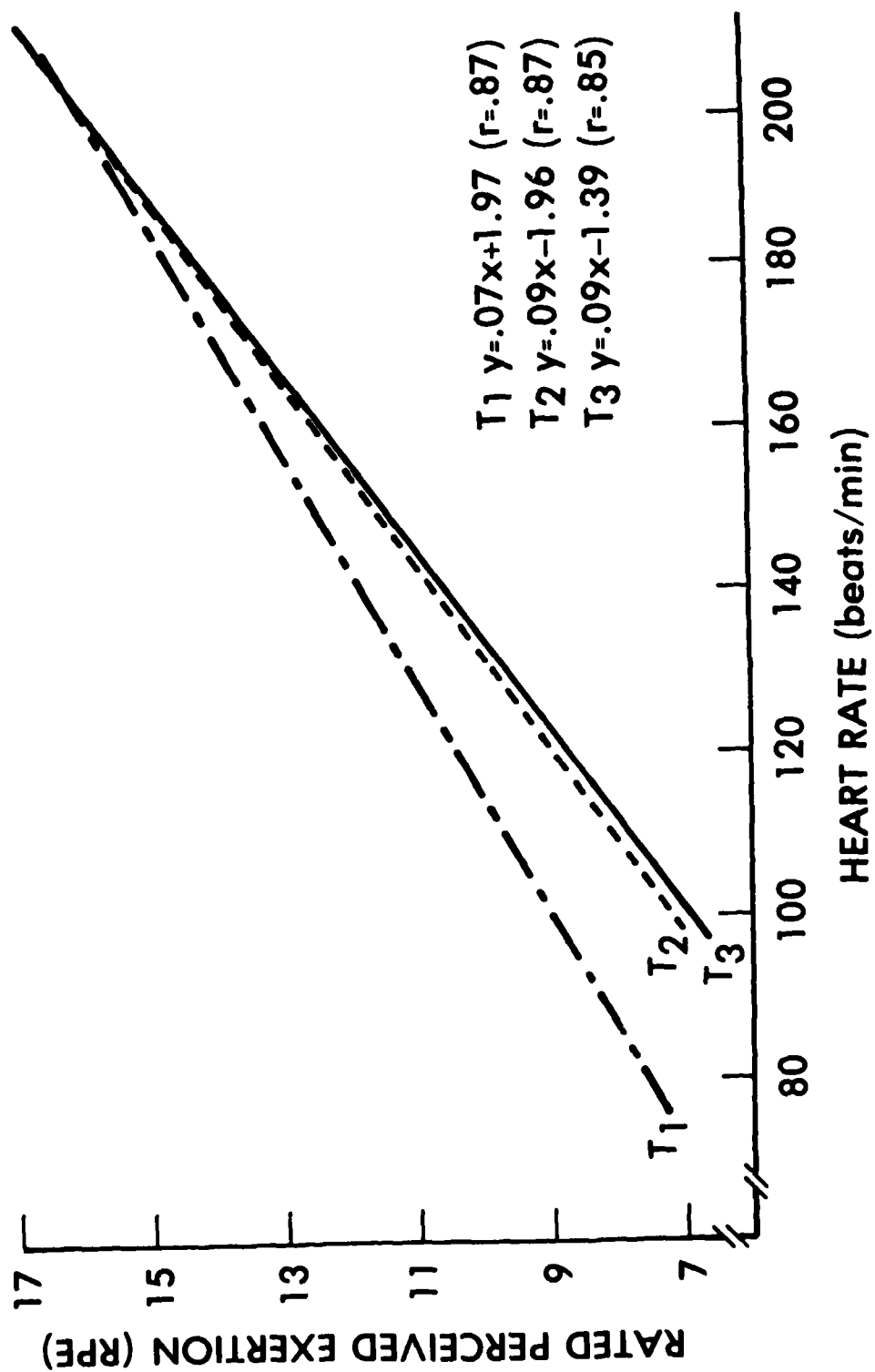17 Very Hard

18

19 Very, Very Hard

20

FIG. 1 Smith et al.

T1 y=.81x+4.53 (r=.83)
T2 y=.83x+4.20 (r=.85)
T3 y=.78x+4.45 (r=.85)

FIG. 2 Smutok et al

T1 y=.07x+1.97 (r=.87)
T2 y=.09x-1.96 (r=.87)
T3 y=.09x-1.39 (r=.85)

HEART RATE (beats/min)

RATED PERCEIVED EXERTION (RPE)

FIG. 3 Smutok et al.